C&R TECHNOLOGIES

What's Ahead in the Thermal Desktop Suite

with Feature Demonstrations

Presented at TFAWS 2020

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Agenda

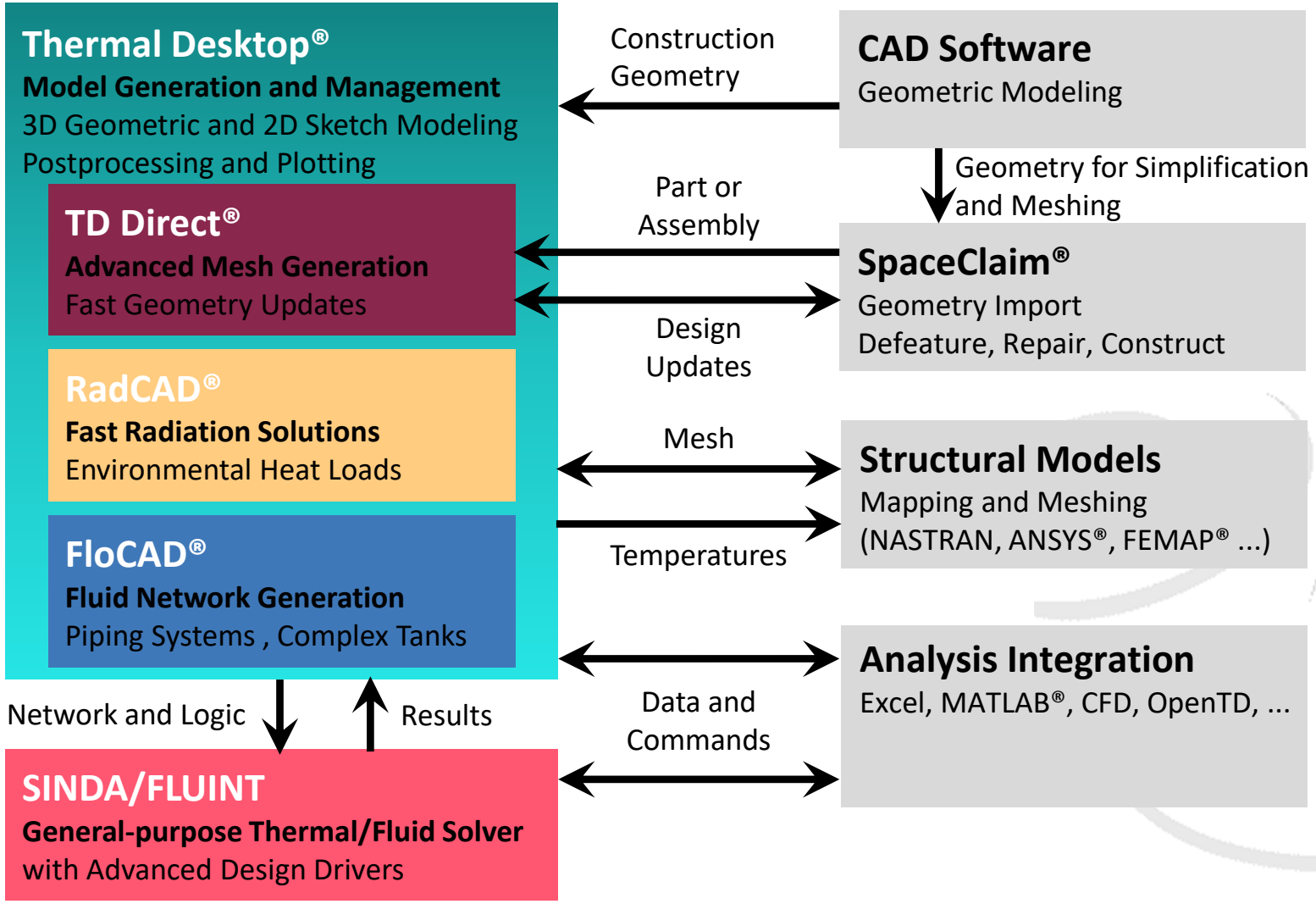
- Overview of CRTech products
- New and upcoming features
  - Thermal Desktop User Interface
  - TD Direct
  - SINDA/FLUINT
  - OpenTD
- Feature Demonstration (time permitting)
- Questions

OVERVIEW OF CRTECH PRODUCTS

C&R Technologies
Tool Suite Overview

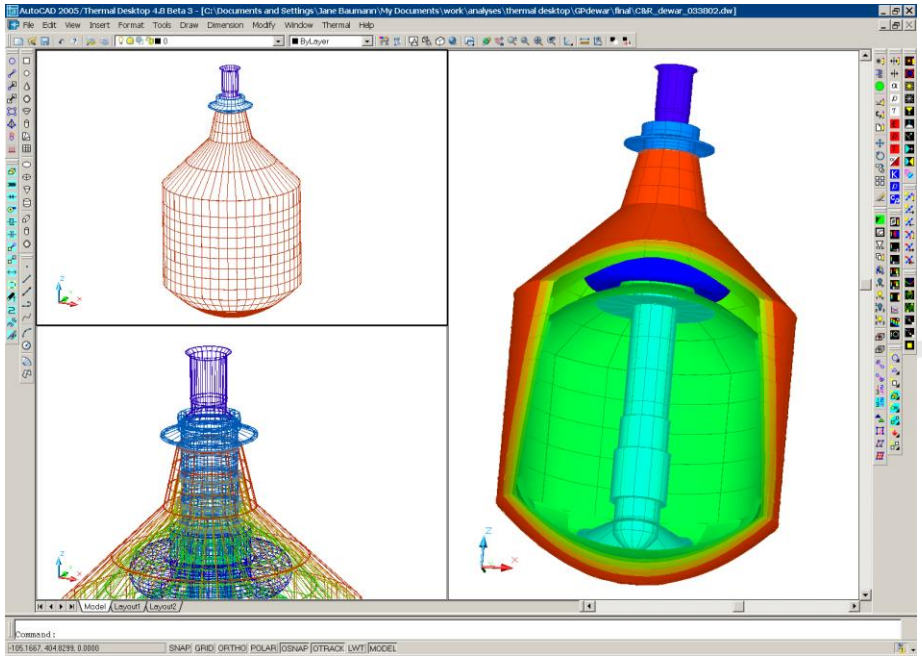
- Thermal Desktop®(TD): AutoCAD-based thermal modeling environment
  - RadCAD module for thermal radiation, orbital environments
  - FloCAD module for heat pipes and fluid networks
- SINDA/FLUINT (S/F)
  - Batch-style solution engine
- TD Direct® (based in ANSYS SpaceClaim)
  - “Upstream” tool for CAD import/clean-up, mark-up, adv. meshing

The Bigger Picture



Thermal Desktop

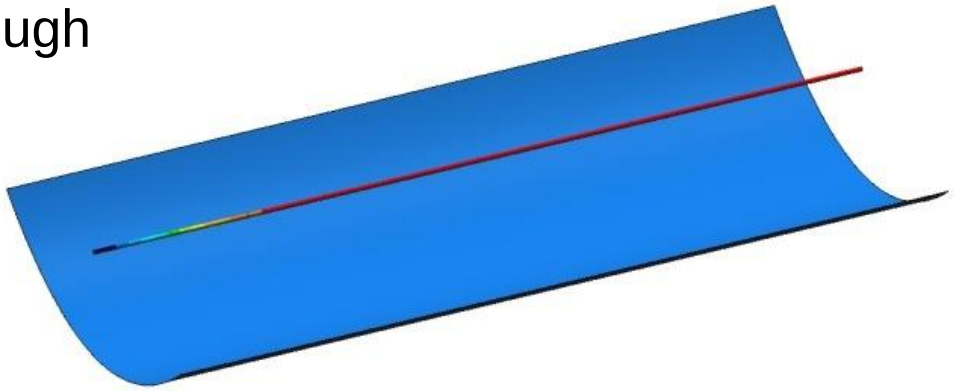
- Generates thermal network based on geometry
  - Finite elements
    - Internally meshed, or imported
  - Finite difference surfaces and solids
    - Finite difference conductance
    - Mathematically correct surfaces: resolution-independent shapes
    - Parametric for goal-seeking and optimization
  - Lumped parameter
- SINDA/FLUINT “under the hood”
  - Single interface for model creation, radiation calculation, solution initiation, and post processing
  - Dynamic mode allows solution results to drive geometry

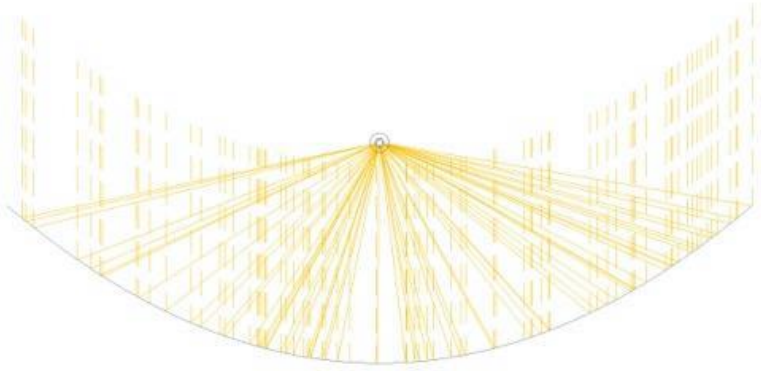


Finite Difference Surfaces and Solids

- Mathematical surfaces
  - Resolution independent shapes
  - Accurate radiation reflections
  - Parametric
  - Snap to geometry

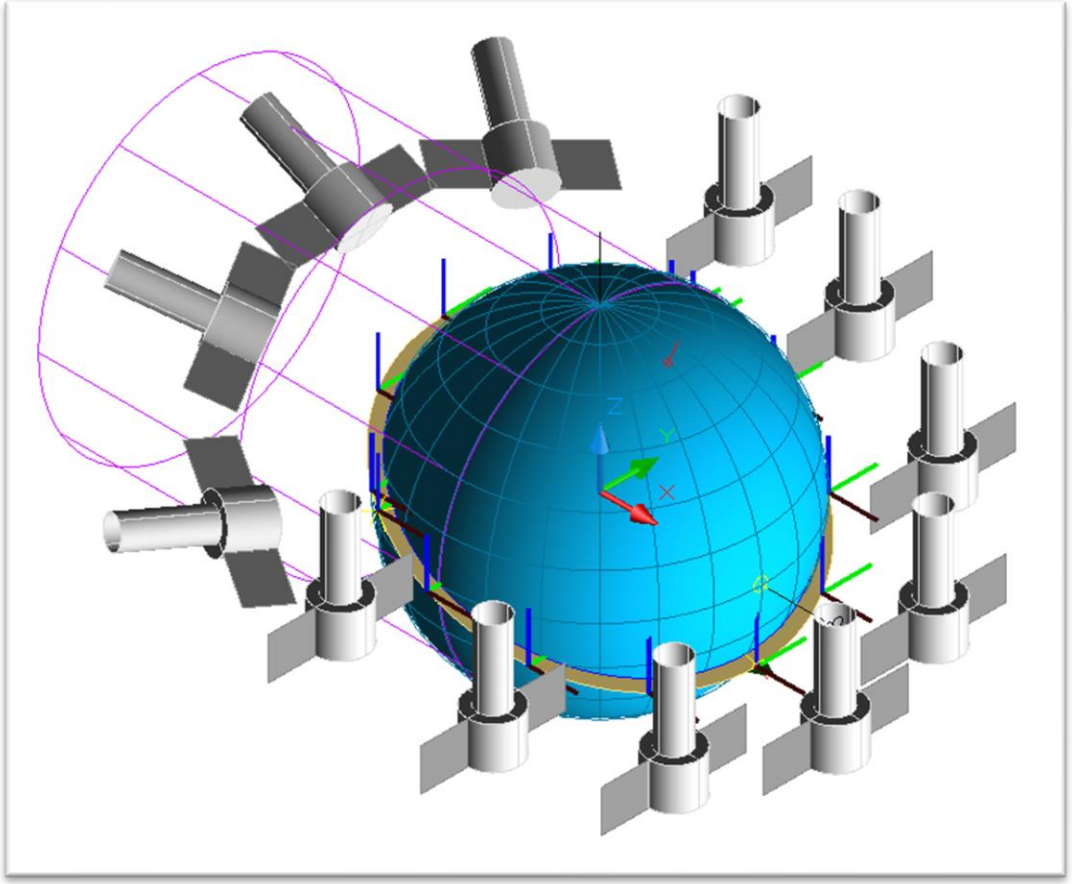
- Example
  - Parabolic trough





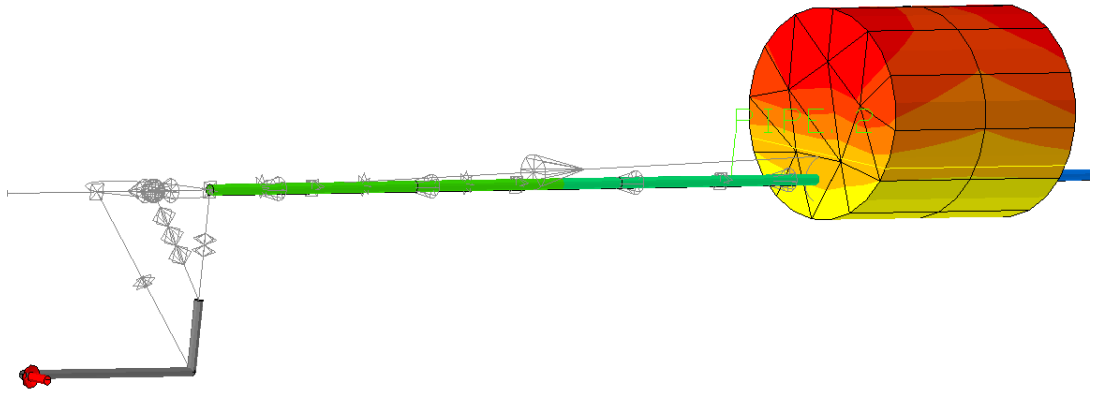
Thermal Desktop Module: RadCAD

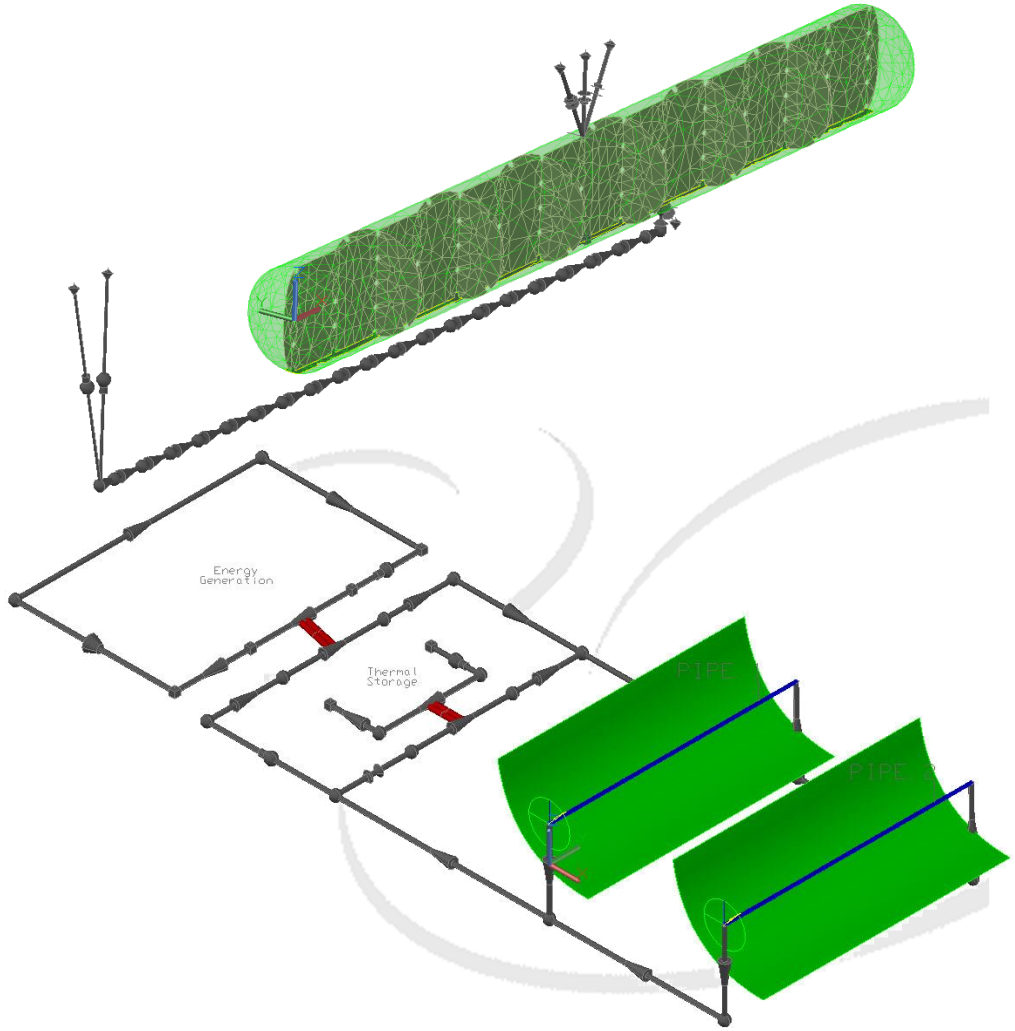
- Calculates surface-to-surface and environment-to-surface radiation
  - Monte Carlo or radiosity methods
  - Gray-body or non-gray radiation
- Environmental source trackers



Thermal Desktop Module: FloCAD

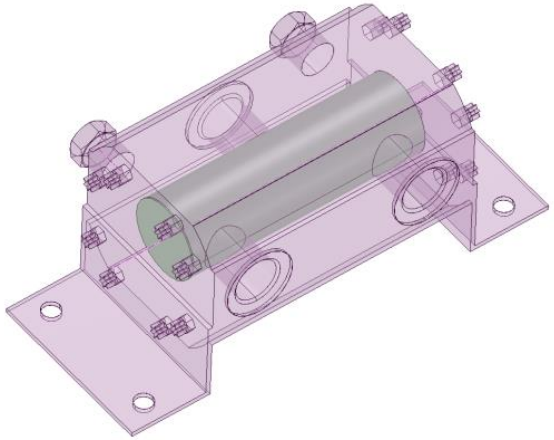
- Generates fluid network
  - Based on geometry or sketchpad
  - Pipe and heatpipe objects
  - Complex tanks (vessels)
  - Connectivity to thermal surfaces and solids

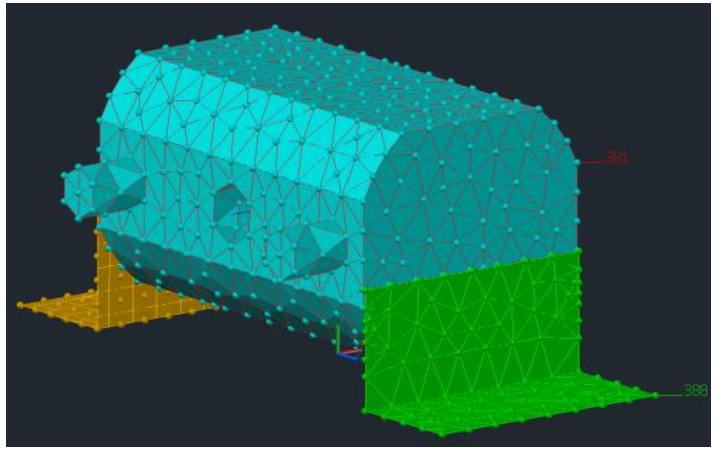


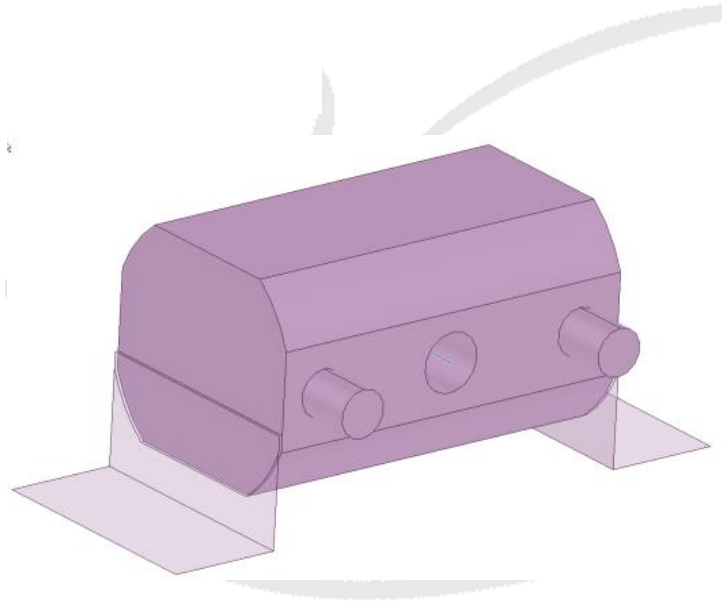


ANSYS SpaceClaim

- Advanced push-pull CAD geometry creation (best-of-class direct modeling)
  - Easy to learn, use, and retain
- Import almost any CAD part or assembly
  - Clean, heal, defeature (including STEP/IGES)
- Prepare for analysis
  - Midsurface, extract volumes and centerlines, project contact areas
  - Tag thermal features
  - Control meshing

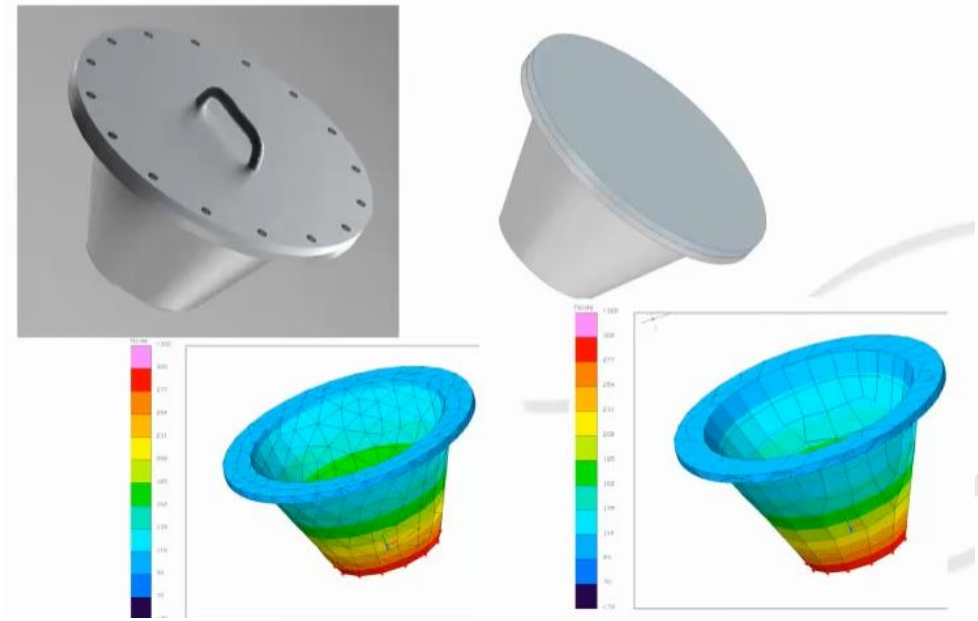


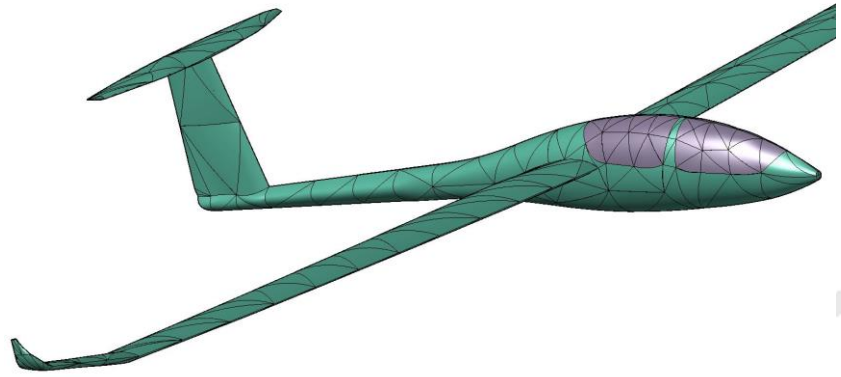




TD Direct

- Advanced Meshing
  - Quad elements
  - Non-manifold meshes
  - Localized control
  - Merge/Match
  - Curved elements
- Property assignment
  - Radiation and thermophysical
- Thermal mark-ups
- One-step updates





CRTech Strengths

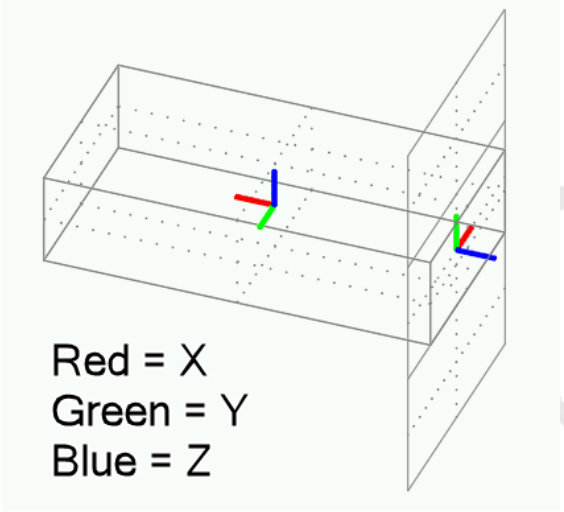
- Strong thermohydraulics, especially two-phase
  - Many unique applications that can't be solved any other way
- Strong thermal radiation and orbital environment tools
- Unique tools for aircraft fuel tanks and space/launch propulsion
- Unique strengths in user-extensibility and customization
  - Competitive as-is for new technology, or new design questions for old technologies: R&D users love it
- Unique focus on system-level (vehicle-level) transient thermal design simulation
  - Examples: curved thermal elements, native perfect geometry elements, compartments, automated calibration to test data

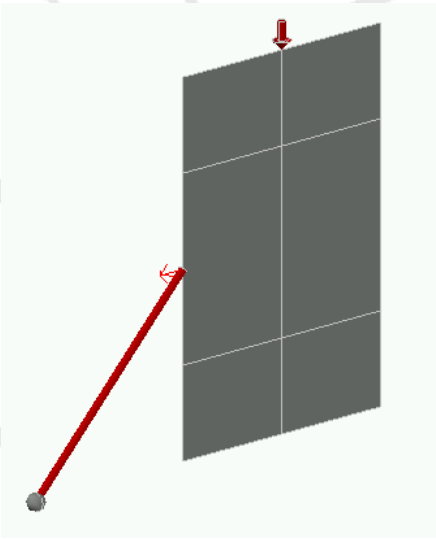
Recently Added or Upcoming

NEW FEATURES

Thermal Bodies (FD or FE)

- Insulation enhanced (6.2)
  - Thin shells *and* FD solids can use Offset ID, Submodel (single layer), or Submodel with offset ID for insulation nodes
- FD shells and solids can have internal axes drawn in wireframe mode to assist with understanding the face and edge definitions (6.2)
- Heat loads, heaters, and conductors have been extended to allow applying to edges of thin-shells
  - Heaters can now be applied to nodes





Pipes

- Pipe centerlines can be placed in domain tag sets
  - Domains can be assigned to curves in TD Direct and exported to Thermal Desktop
- Pipes can reference curve domain tag sets for their centerlines

Bottom line: Pipe centerlines can be modified in TD Direct with updates changing the pipes that reference the domain tag set that includes the curves

FloCAD Compartments

- New Register-generation System
  - Allows various Compartment inputs to be inspected or changed during SINDA/FLUINT execution
  - New Tie multiplier parameter (since UAM was already used by Compartments)
- Splash and Spin
  - Allows specification of a splash zone near the liquid surface (fast/small slosh, froth when boiling, etc.)
  - Provisions and examples for use in axial spin (such as BBQ rolls at low gravity)

Thermophysical Properties

- Phase change material (PCM) properties enhanced (6.2)
  - Automatically tallies melt fraction by submodel
  - Allow PCMs to mixed with non-PCMs in laminates and aggregates
    - Example: metal fins or mesh matrix within a container of wax
  - Allow nodes at PCM/container boundaries to have properties of both types of material (avoids adding a large Contactor)
- Accretion added to property options (6.2)
  - Accretion is the build-up of a substance such as ice on surfaces that will affect heat transfer
- Aggregate materials enhanced
  - Volume fraction check for volume fractions summing to one (6.1)
  - Mass fraction option added (6.2)
  - Option added to override the calculated properties (6.2)

Case Sets

- Exceptions allowed for duplicate node checks (6.2)
- Model Kicker allows boundary nodes to be kicked (6.2)
  - Model kicker is a great way to check models by running a series of steady-state solutions with something (domain, submodel, node) “kicked” and the difference in results are displayed
  - Differences show the strength of connectivity in the model
- Accretion settings added to SINDA control (6.2)
  - Accretion is the build-up of a substance such as ice on surfaces that will affect heat transfer

Postprocessing

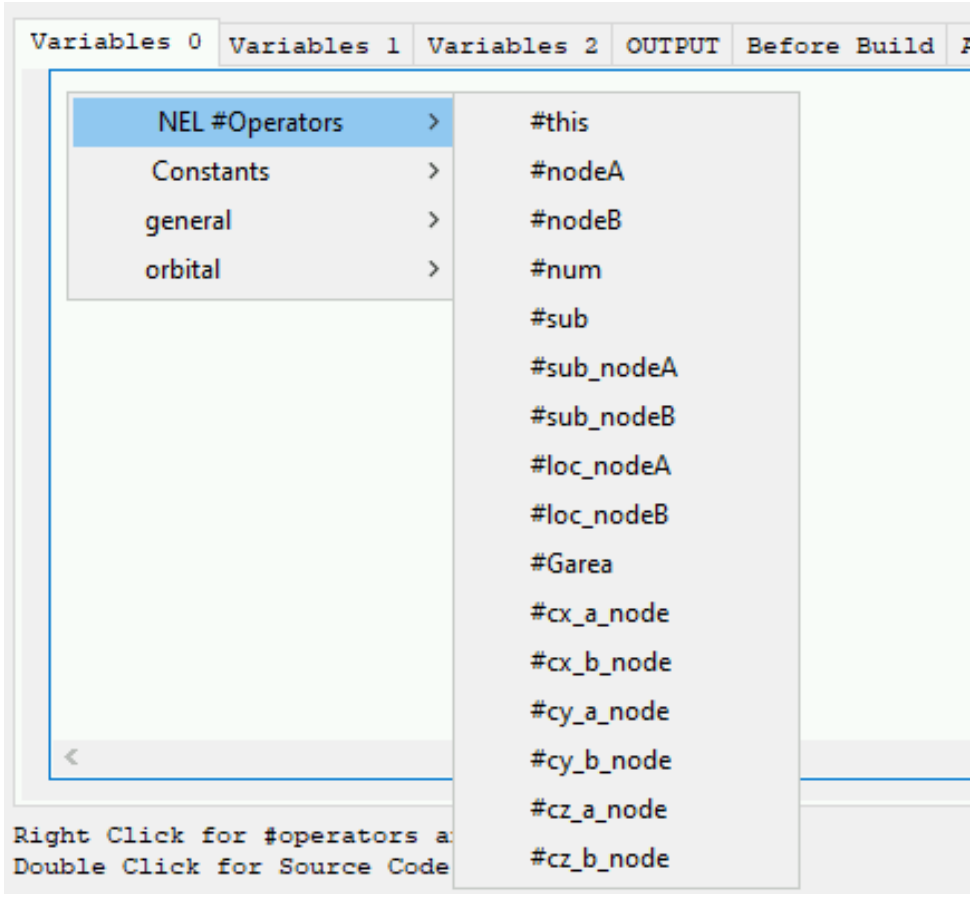
- Color bars can show area or volume as percent option
  - Useful for element quality display
- Lump species added to Thermal Desktop postprocessing
  - XG, XF, PPG, MF, XMDOT, GL, CGL, FRD, FRH, HEN, GT, and CGT
- Conductor G and HR values can be output through Save Results to Text (6.1)
- User-defined FORTRAN Arrays (UDFA) that are sized to nodes, lumps, or other network objects can be referenced by *UDFAname.smn.id* in Save Results to Text and TdText/Smart Annotations (6.1)
  - This effectively allows user-defined variables for network objects such as node enthalpy or path velocity.

Logic Manager

- Convergence waivers added to logic manager to exclude objects from convergence checks (6.2)
- User-defined FORTRAN arrays (UDFAs) expanded
  - UDFAs bring an amazing amount of power to solutions
    - Examples have been created using them for:
      - Recording minimum, maximum, and weighted-average temperatures per submodel
      - Creating user-defined variables such as path velocity
      - Creating unique heater control systems (control to the second-highest temperature in a set)
  - Logical array have been added for use as MASKS in functions (6.2)
  - Character arrays have been added (6.2)
  - UDFAs can be individually controlled for output to results files (6.2)
    - Example: disable output of auxiliary arrays used in calculations that do not need to be postprocessed (logical arrays, for instance)

Network Element Logic

- Right-click list of #operators (6.1), symbols (6.1), and UDFAs (6.2)



Thermoelectrics

- TEC and TEG enhanced to have registers for Seebeck, Resistivity, and Conductivity (6.1)
- TEC and TEG leg-level calculations added (6.2)
  - Allows advanced thermoelectric designs to be simulated including:
    - Distinct P-doped and N-doped leg materials, aspect ratios, and even number of legs
    - Enables segmented legs with user-calculated composite leg properties

Radiation Calculations

- Radks and heating rate arrays can use ASCII or binary files (6.1)
  - Binary files decreases preprocessing and file generation time

Boundary Condition Mapper

- Mapping improved to search for a single objects (6.2)
- Conductor and Temperature pairs enhanced for binary arrays to improve preprocessing, SINDA file generation, and interpolating (6.2)

TD Direct

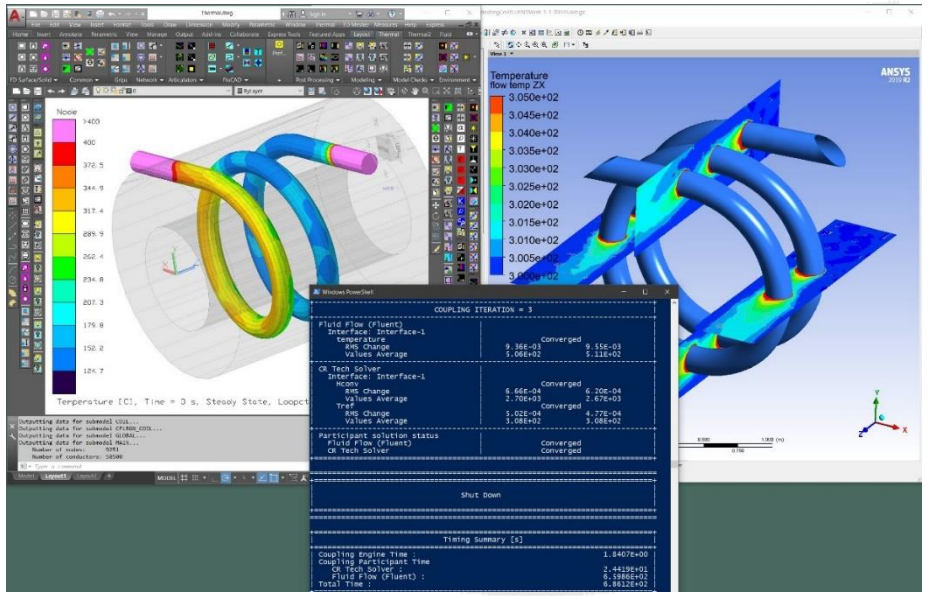
- Suppress for Physics can be set and viewed with TD Direct (6.1)
  - Suppressed objects are not meshed
- Domains with matched regions will generated *Free* domains of unmatched regions (6.1)
  - Matched regions are typically locations of contact
  - Unmatched regions might be used for convection
- Curves can be used to align material orienters (6.2)
- Curves and lines can be assigned Domains in TD Direct and exported to Thermal Desktop for use in pipes (6.2)

SINDA/FLUINT

- Path linker utility helps split and join fluid submodels
  - Often required to change working fluid descriptions within a flow system because of temperature range changes, condensable mixture limits, or distinct reagent/products for chemical reactions
- Make one or more tanks act as temporary junctions in transients
  - Avoids having to use multiple drawings with different tank vs. junction decisions
- Iface velocity query for advanced valve modeling, simulating moving liquid slugs

Co-solving with ANSYS Fluent

- Integrating CRTech simulation products with ANSYS Simulation
  - Through partnership with ANSYS
  - Conjugate Heat Transfer with Radiation and 1D Fluid Flow (6.2)
    - Easy to use –
      - Proficiency with Fluent and Thermal Desktop recommended
      - System Coupling well documented and supported
    - Advanced coupling algorithms for stability and speed
    - Built-in feature, licensed with simulation products

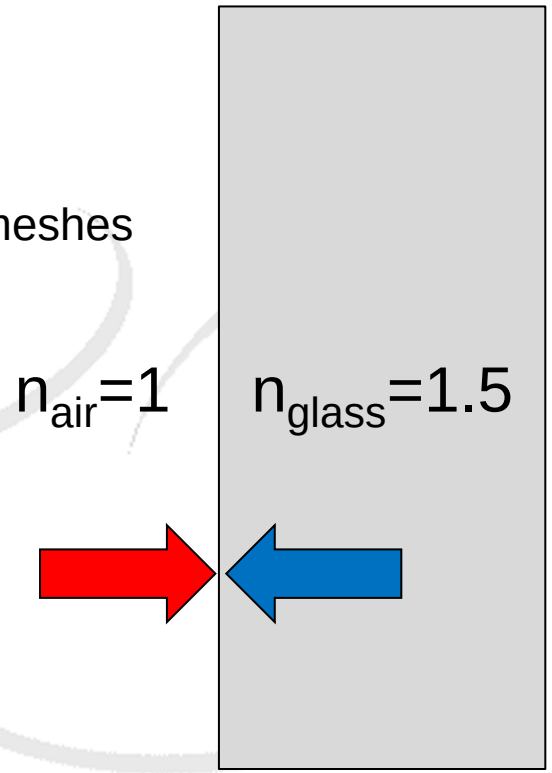


As time permits

FEATURE DEMONSTRATIONS

Transmission and Refraction

- Transmission
  - For n transmitting faces where subscript T is for the total property
    - $\tau = \sqrt[n]{\tau_T}$
    - $\epsilon = 1 - \tau - \rho_T$ for reflective surface (1st or 2nd surface mirror)
    - $\epsilon = 1 - \tau$ for other surfaces
  - Thermal Desktop performs radiation calculations at the surfaces
    - n=2 for Thermal Desktop finite difference solids and surface-coated solid meshes
- Refraction
  - Refractive indices ratio is the ratio in the direction of the ray
    - From air to glass is $n_{air}/n_{glass} = \frac{1}{1.5} \rightarrow$ Outside optical properties
    - From glass to air is $n_{glass}/n_{air} = 1.5 \rightarrow$ Inside optical properties
  - Values on opposite faces must be reciprocal
    - Use expressions: $\frac{1}{1.5} \neq 0.667$



Setting up a Timed Event

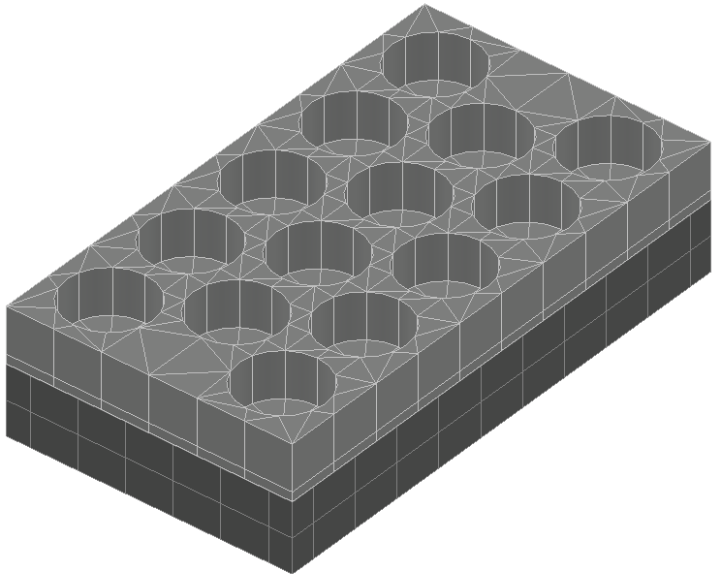
- Using OUTPUT CALLS enforces a time schedule
  - Automatic timesteps are adjusted to meet the output calls
    - Timesteps can be shorter than output intervals if required
    - Timesteps will never overstep an output interval
- How to set it up
  - Identify a submodel(s) for the event – *submodel*
  - Use OUTPUT CALLS, *submodel* to update the event
  - Set *submodel*.OUTPUT to the inverse of the frequency
    - This should be added in a Post-Build logic object
    - The Output interval on the Case Set Output tab sets OUTPUT for all submodels
    - OUTPUT CALLS, *submodel* and OUTPUT CALLS, GLOBAL are both executed every *submodel*.OUTPUT
  - On the Case Set Output tab, choose an output submodel that is not (Auto) or *submodel*
    - The (Auto) option places all logic for output (writing to text and results files) in the GLOBAL submodel
    - Using (Auto) or *submodel* will generate the outputs at the same frequency as the event

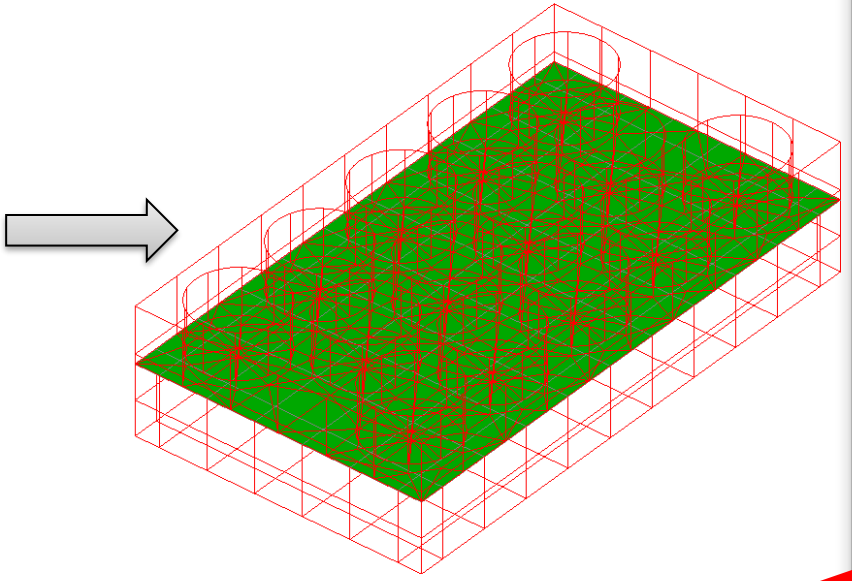
Timed Event Example

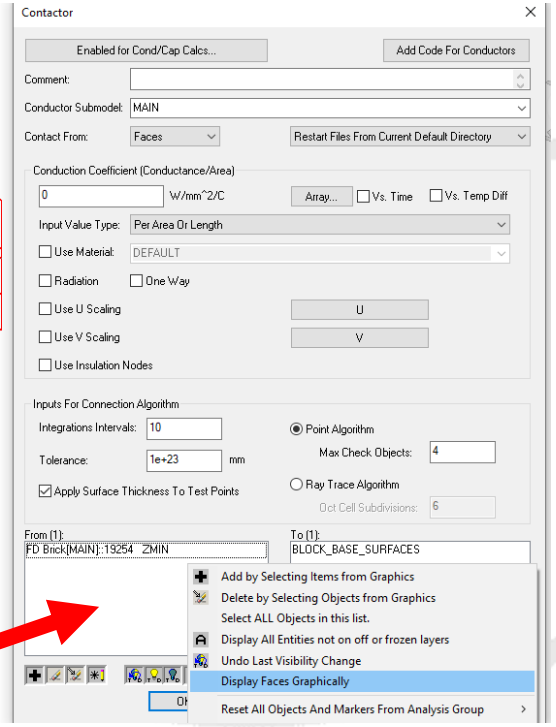
- Heater with a sampling rate of 5 Hz (submodel = HEATER)
  - Use a boundary node as the sensing object (submodel.id = HEATER.999)
    - You control when the value is updated
  - In OUTPUT CALLS, HEATER, update HEATER.T999 (the temperature of the sensing node)
    - Possibly point to a temperature measure
  - In the Post-Build Logic, set HEATER.OUTPUT = 1./5.
  - On the Case Set Output tab set the output submodel to something other than (Auto) or HEATER and set the desired output interval for results

Graphically Display Contactor Active Faces

- Right-click to display contactor From active sides
  - Double-check which surfaces are active before completing the contactor
  - Available for Face Contactors







Right-click here to access

Object List Faces